A Smart Paper Feeding Unit for Printers using the Mechatronic Technology

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Abstract

In order to add more functions to a PC printer, a new feeding unit is inevitable. The present paper reports a preliminary design idea for printing a thick object by a mechatronic way. The new design was started from analyzing the basic function kernels together with generating ideas using the creative design methods. Once the design goal was set, a 3D model was then established to simulate and evaluate the feasibility of the chosen idea and goals. In the meantime, the controlling flow was programmed according to the feeding proposal. Furthermore, the whole idea has been completed and tested in the lab. It has been found that the new design can smartly sense the thickness of inserted printings and determine the optimal force that need to drive the objects. It can successfully handle printing objects with thicknesses from a normal paper to 10 mm cardboards. The results are quite promising even though the present study is only a down-scaled one.

keywords: paper feeding mechanism, Paper feeding unit, printer.

1. Introduction

In general, the paper feeding system using friction force providing from rubber rollers is commonly seen in compact printers. However, there exist two problems in such feeding systems. One is the accuracy of paper positioning which stems from the rubber rollers are difficult to provide sufficient and constant normal forces so that the lateral deviation can hardly be avoided. This problem is especially important when the span of paper sizes becomes wider. The other problem is that the thickness spectrum of the feeding papers is limited. In order to maintain the minimum friction forces between the two contact rubber rollers, the thickness of the paper can be only within small ranges. Otherwise, the manual re-adjustment may be required.

For the first problem, Japanese researchers [1] have studied in the paper motion under skewed rubber rollers. They [1] concluded that the skewed roller causes only on the lateral motion, which is proportional to the skew angle between rollers, and not on the longitudinal motion. However, their study did not give any solution to minimize the skew angle occurs from the rollers. Hence, [2] independently provided a new idea to pick papers based on electrostatic forces, instead of friction forces through rollers. He claimed that the new device can be used for low friction materials. Besides, since the electrostatic forces are uniformly distributed over the entire paper surface, it can be used to drive papers that are both thin and delicate. However, such electrostatic forces are so sensitive to the humidity condition of the paper surfaces that slippage may be severe in some circumstances. Hence, there exists no chance to replace the traditional rubber rollers. It is true, in general, that the contact condition between two adjacent surfaces of paper and roller is very important [3] for designing a feeding unit. Unfortunately, the paper condition normally cannot be foreseen or controlled by the designer. For the second problem, on the other hand, it seems seldom researchers are concerned, to the authors' knowledge.

Usually, it has to include control technologies into the feeding unit in order to optimize the paper feeding capability of printers. Not to mention the quality of prints, which involve even more domain technological knowledges, the feeding speed and positioning can be the two fatal factors in the design of paper feeding units. In order to improve the picking capability of printers for light weight under high speed condition, [4] faced the challenge of 18” wide and 20” or more in length at speeds of 130 ft/m. They [4] found that the mechanical instability, subjects to aerodynamic and impact forces, caused the paper ripples and was the most significant factor. The solution they gave and tried was to dampen paper. In addition to this, electro-mechanical feed motion profiles, which supposed to be the optimal, were developed so that the printer is capable of agilely adjusting the feeding characteristics depending on the physical properties of the fed papers.

Actually, there exist several researches to improve the performances of currently used printers. For example, [5] utilized a FEM commercial package to analyze the friction force of the feeding mechanism. In the study, the traditional Coulomb friction model with small modification was used in the numerical analysis. In addition, a simple equation was presented to predict the paper velocity and friction force. Basically, [5] assumes printers of the rubber roller type will be the mainstream in the printer industries. The authors agree this point of view that because the cost of a friction force printer is the lowest. However, it is apparent that it has to include more functions like automatic document feed (ADF) [e.g., 6,7] are necessary for modern printers. Besides, the most researches have been focused in topics like positioning accuracy [e.g., 8], friction forces, feeding speeds, etc. Not much attention is caught by topics in its thickness.

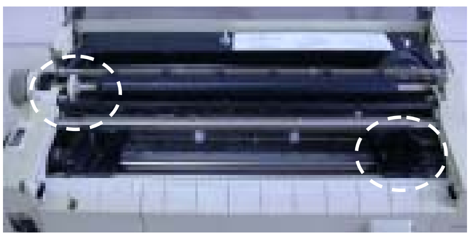
Recently, the first author conducted a random survey by asking the potential printer users for the possible functions they need in case that he or she has a chance to create an ideal printer. It turned out that lots of answers are focused in printing their CD's or their thick birthday cards. That is, the potential users expect the future printer can be used to show their own characters. Motivated by this, the present paper tries to bridge the gap between the existing printers and 'ideal' ones by providing a self-sensing device. In addition, the whole feeding mechanism has to be improved or re-designed to accommodate the newly added function. The developing processes and results are briefly discussed in the present report. For the detail, one is referred to [9].

2. Current Status

The current status for the paper feeding units in current printers will be reviewed in this section. However, since there are too many types and brands to completely review, one just chooses a few that commonly seen in the market. For others, the small deviation may be observed.

2.1 Dot Matrices

The early printers are the so-called 'dot matrix' type. They are good for imprinting a few carbon copies simultaneously. Fig. 1 shows the paper feeding mechanism of such a printer that commonly seen in the market. Basically, the mechanism composes two geared belts, one along each side, to feed papers. Thus, their counterpart, papers, has to be punched holes with the same pitch as that on the feeding belts. In addition, the two gears on the each belt have to be well aligned so that the forward/backward motions of the two belts can be kept in the same. Meanwhile, the positioning accuracy completely depends on the accuracies of the pitch and hole sizes on the paper. Therefore, this feeding mechanism has poor positioning accuracy and is out of date.



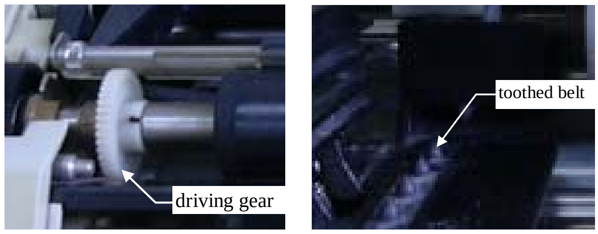


Fig. 1 Feeding unit of a dot matrix printer.

2.2 Ink Jet and Laser Jet

The shortcoming of the dot-matrix type printer is quite apparent. The most market of this type was thus soon replaced by so-called ink jet printers. Unlike the dot-matrix ones, the feeding unit does not provide any gear teeth. Instead, two rollers are installed for responsible of feeding papers. Fig. 2 shows the unit. In general, one of the two rollers is used for guiding only. It normally divided into several shorter sections and all made of soft materials. And, the other is for driving and driven by a motor. The basic feeding mechanism of this feeding system stems from the friction force that exists from pressing the driving roller to the guide. Normally, the pressing roller has an adjusting spring for manually tuning the pressing forces and the gap between the two rollers.

The position accuracy of this type is believed to be much better than that of a dot matrix. However, there also shortcoming has been observed. For example, the skewness of one or two rollers can easily result in the papers difficult to parallel. Besides, the surface condition, especially from the driving roller which is normally made of rubber, may wear out after a certain period. Furthermore, it may easily jam the fed paper if it is too thick. However, it costs less and is easy to manufacture. To the authors' know- ledge, printers of this type are still popular in today's market.

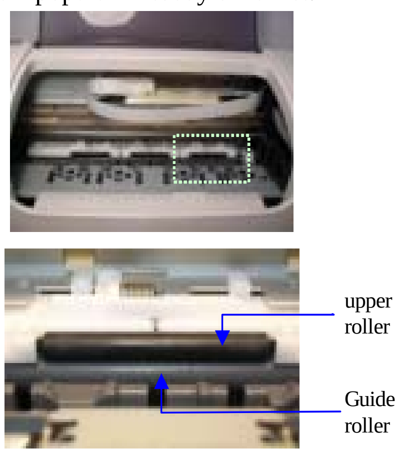


Fig. 2 A typical feeding unit of ink-jet printers.

In facto, the feeding unit of this friction roller type has been modified and improved in many ways. For instance, Fig. 3 shows an Epson's model Photo 2100 [10] which is claimed to have the capability of printing on a CD. A tray that fits the size of a CD has been added. This model is quite fancy but the cost is high as well. To the authors' knowledge, this type of paper feeder does not have good responses from the consumers.

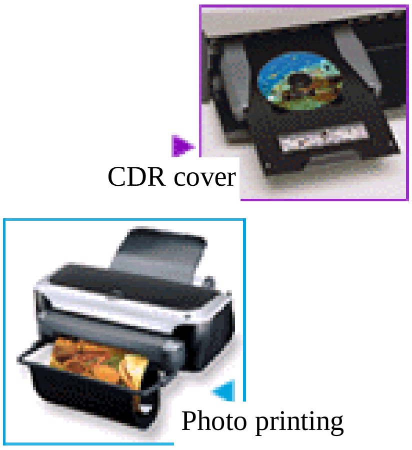


Fig. 3 A paper feeder with a CD tray.

Since this type of feeding system is cheap and relatively reliable, it also is being used for laser jet printers. Figure 4 shows a typical feeding unit from HP's laser jet printers [11]. It can be clearly seen that there exist two rollers, which are the key technology of the feeder from the picture.

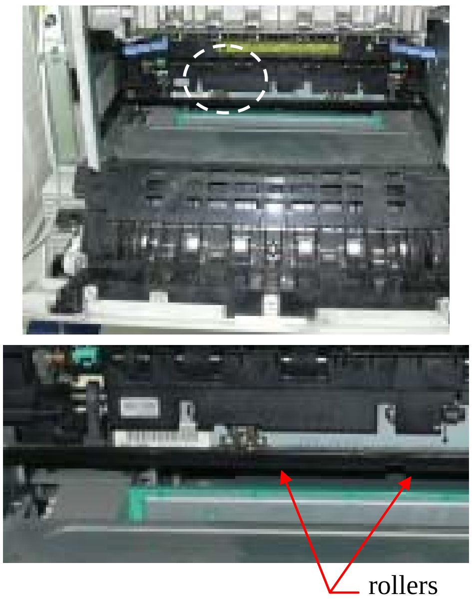


Fig. 4 Friction rollers of an HP laser jet printer.

2.3 Thermal Transfer

Unlike the former printers, a thermal heat transfer printer requires to move the printing paper back and forth several times in order to overlay the image with different colors. Thus, the feeding mechanism normally includes a capstan driving roller, which is driven by a motor, together with an upper rubber roller. The capstan roller is made of light metallic material (e.g. aluminum alloy) embossed with equally spaced small dots (or similar geometry) that similar to Braille. Once the capstan is uniformly pressed by the rubber roller, the interface between them generates much higher friction than that of the traditional friction rollers. The rubber roller may even have dents that developed by the embossed dots on its surface. The dots on the capstan surface play an important role of moving the paper back to the origin each time when one color being completed. Therefore, the higher quality of an image is required, the more precise of such motion has to fulfill. And, the surface characteristics of the capstan roller can completely determine the moving and feeding precision. Figure 5 shows a typical capstan and the rubber roller. Notice the surface characteristics of the two rollers.

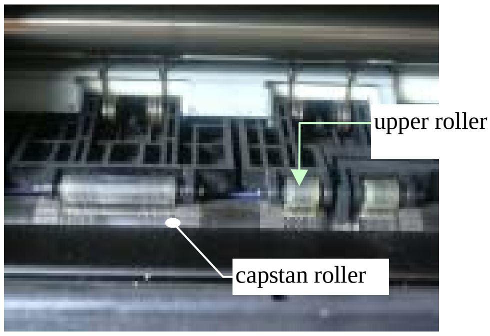


Fig. 5 A feeding unit for a thermal transfer printer.

3. The Present Design

3.1 Mechanism

From the theoretical point of view, the only currently used paper feeding is based on the friction force that is generated from the normal contact force exerted from the two contact bodies. To increase the friction force, one has two factors can be controlled: the coefficient of friction and the normal forces. And, it seems to the authors that this way of pushing paper is simplest and cheapest. Thus, the present design keeps this friction type.

On the other hand, in order to generate a large and controllable normal force, new design ideas have to be generated prior to embodiment design. In order to reach this target, the basic functions have been first analyzed in addition to study the current status. The creative methods introduced in [12,13] have been applied during this stage and several new ideas were generated through those methods. It has been found the brain storming method is the most effective one. For example, Fig. 6 shows two typical ideas that have been discussed during the idea generation period. However, they were all discarded since poor precision may occur during the assembling or difficult to manufacturing.

Figure 7 shows the one that has been selected for the mechanism prototype of the present feeding unit. That is, it combines the two ideas in Fig.6 in addition to several small modifications. It can be clearly seen that the new design still encloses the central idea of the friction rollers. Besides, anticipating the roller is going to be driven by a stepping motor, a lead screw has been added. In the meantime, it can also see that there are two guide bearings or surfaces, which are mainly for uniformly increasing the force distribution. In fact, the roller has been designed to cover a fine sand paper of #500 in addition to soft rubber. Hence, a higher friction coefficient can be expected. Fig. 8 shows the picture of the two rollers, where the sand paper has been covered on their surfaces.

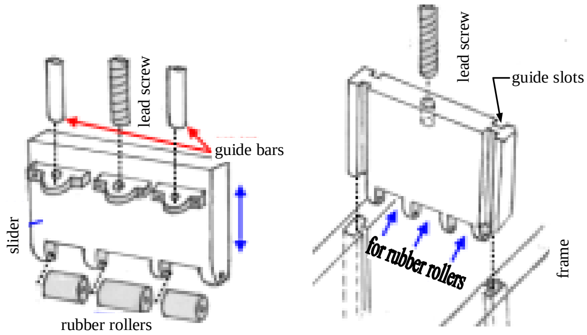


Fig. 6 Two typical ideas for a new feeding unit [9].

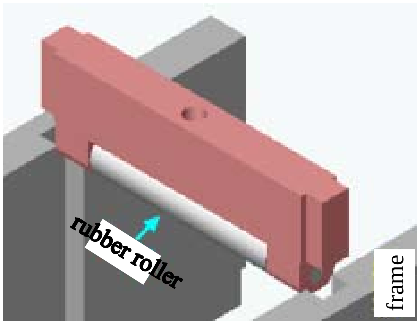


Fig. 7 The schematic 3D model of the present design.

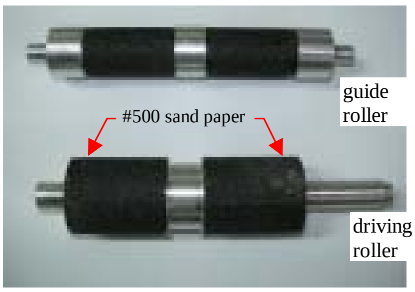


Fig. 8 The two rollers of the present design.

3.2 Sensing Devices

There are two types of sensing devices have been installed. One is to sense the pushing load from the rubber roller on to the driving roller. This downward loading signal is definitely proportional to the amplitude of the friction force between the two rollers. However, since it is difficult to directly measure the contact force, instead, one has to measure the bending moment exerted from the support of the driving roller. The basic idea is depicted in Fig. 9. In this case, a strain gauge has been applied since it costs less and is quite reliable.

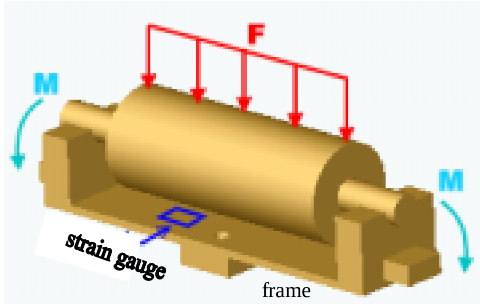


Fig. 9 The device for sensing friction force.

The second type of sensors is the micro-switches (MS), which are used for detecting the position of the printing paper. There are three MS have been included in the present feeder. They are used for (1) paper arrival (MS1), (2) paper in place (MS2), and (3) end of paper (MS3), respectively.

3.3 Control and Monitoring Flow

The control flow of the present feeding unit is quite simple, and briefly described in Fig. 10. And, ATMEL 89C51 (8051) [14] has been chosen as the micro-processor in the experimental period. The necessary program is established from Window Notepad before compiling into machine code, and will not shown in the present report. Readers are referred to [9].

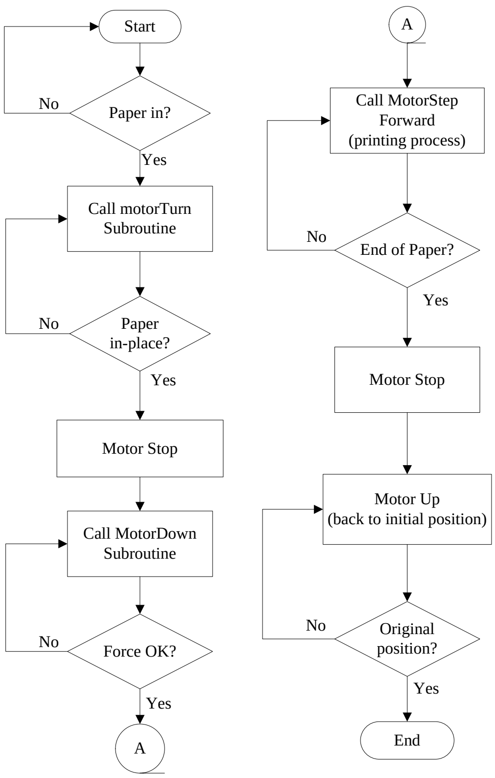


Fig. 10 Control flow diagram.

4. Results and Tests

4.1 Mechanical Parts

In order to verify the idea depicted in the last section, all mechanical parts were designed by using a 3D commercial package (Solidworks) before they are made. For example, Fig. 11(a) shows the downward mechanism together with the stepping motor (4ϕ × 12V), in CAD model while Fig. 11(b) is its completed product assembly. One is able to see their similarity. Nevertheless, the CAD tool has been widely utilized during the generation of the present feeding unit. Since the main purpose of the present study is to verify the feasibility of the novel idea, only the scale-down size of the feeding unit was made. All mechanical components were machined in the lab of NTUT, in addition to some small standard elements (e.g., plastic pinions) can be easily bought in the market.

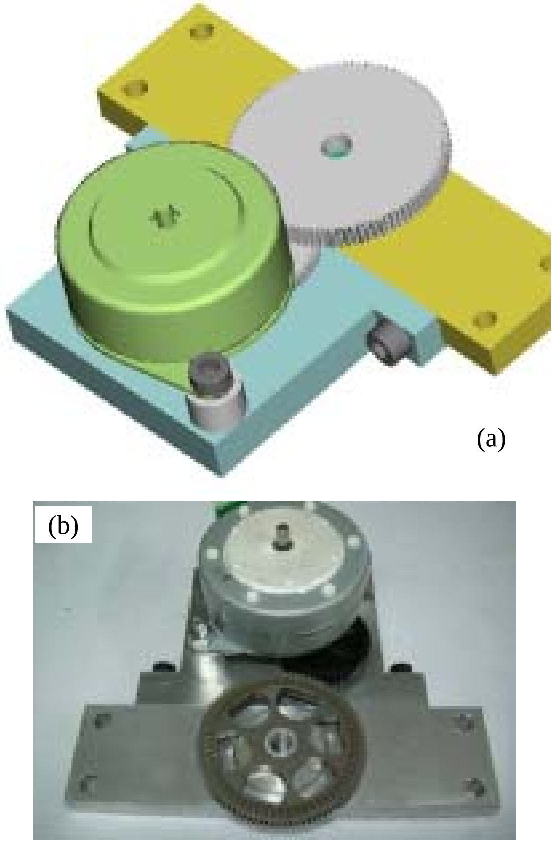


Fig. 11 The downward mechanism assembly.

Since the driver stepping motor normally doesn't provide enough toques, to increase its output torque needs to reduce the rpm, which equally means more mechanical elements have to be added. In this situation, the biggest problem in manufacturing these parts is the fit of two parts. However, after several trials, quit satisfactory components can be produced in the lab. The complete assembly is shown in Fig. 12. It has shown three main sub-assemblies in the figure: the feeding unit, the power supply, and the control unit. Even though the final product has neither been integrated into as one complete set nor pretty enough, it works as the specified design goal.

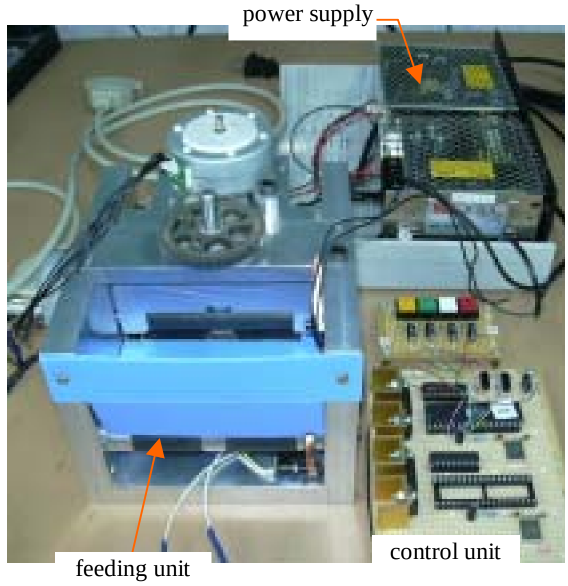


Fig. 12 The three sub-unit of the feeding unit.

4.2 Function Tests

The prototype feeding unit, including all controls, has been experimentally tested after it was assembled. In order to see whether the original design goals have been reached or not, several different objects were purposely inserted into the present unit in addition to thin printing papers. These extra thick objects are supposed to be very possibly being printed by a user. Figure 13 shows a 3.5" floppy disk was being tested. For every object, thirty (30) times were tested, and pass or fail fully depends on if the printed object could smoothly go through the unit. In case the object was jammed or zigzagged during it went through the unit, that test was then graded fail. The final experiment results are tabulated in Table 1.

Fig. 13 A 3.5" floppy disk is fed into the unit.

Table 1 Tests with various printing objects

Objects	Trials/Fail	Pass rate	Remarks
3.5" floppy disk	30/0	100 %	
700 MB CD-R	30/2	93.3 %	
Acrylic, 3 mm	30/0	100 %	
cardboard paper 6 mm corrugated	30/3	90 %	
cardboard paper 10 mm thick	30/0	100 %	

From the summary of the extra thick printing tests in Table 1, one may see the present feeding unit cannot reliable results for cases of CDR and corrugated card papers. The main reason for the former one is that the limitation of its geometric shape is circular. Thus, it is difficult to keep inserting a CDR properly aligned with MS2. As the consequence, the CDR may jerkily sway to one side, instead of smoothly moving. Even though it did go through the entire span up to MS during the tests, the results have been graded to fail.

For the reason of fail in tests of corrugated card-board, the main reason stems in the non-homogeneous of the board. Those of reinforced areas, it appeared stiffer than those of none. After repeated tests for 30 times, the cardboard has been pressed and deformed to completely different from its original shapes. However, since the embedded controller still works fairly well as what the design goal sets up.

5. Conclusions

A novel design of the paper feeding unit for printers has been completed. The design was started from analyze the basic function kernels together with using the creative engineering design method to generate ideas. After the design goal has been set, a 3D model was then established in order to simulate and evaluate the feasibility of the chosen idea and goals. In the meantime, the controlling flow was programmed according to the feeding needs. Three sensors were determined to add for the need of feeding control. Furthermore, the whole new idea has been completed and tested in the lab. It can smartly sense the thickness of inserted printings and determine the optimal force that need to drive the objects. It has been found that the present feeding unit can fairly well handle printing objects with thicknesses from a normal paper to 10 mm cardboards. The results are quite promising even though the unit is only a down-scaled one.

6. Acknowledgement

The present research was financially supported by National Science Council of Taiwan under Project No. NSC-92-2815-C-027-007-E. Gratefully thanks are due to NSC.

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